AFTON PLASTICS

# PVDF Material Properties Data Sheet

PVDF (polyvinylidene fluoride) is a melt-processible homopolymer with a recommended upper continuous-use temperature of 150°C (302°F). PVDF exhibits excellent mechanical strength and toughness, stiffness, high dielectric strength, abrasion resistance, creep resistance, high purity, chemical inertness, low flammability, and low moisture absorption. These properties make PVDF a preferred product in applications, such as, gaskets, pipe, fittings, valves, and pump parts for the semiconductor and chemical processing industry.

| **Mechanical Property** | **ASTM Method** | **Unit** | **Kynar® 1000 HD**[1] | **Hylar® MP-10**[2] |
|---|---|---|---|---|
| Melt Flow Rate | ISO 1133 | g/10 min | 1.5-2.5 | 7-10 |
| Specific Gravity | D-792 | | 1.78 | 1.78 |
| Water Absorption, 24 hr. | D-570 | % | 0.03 | 0.02 |
| Tensile Strength, 23°C | D-638, ISO R-527 | psi | 7,105 | 7,395-8,250 |
| Elongation, 23°C | D-638, ISO R-527 | % | 250 | 50-250 |
| Compressive Strength, 23°C at 5% strain | D-695 | psi | -- | -- |
| Impact Strength, 23°C, Notched Izod | D-256 | J/m | 160 | 100-200 |
| Flexural Modulus, 23°C | D-790, ISO 178 | psi | $130 \times 10^3$ | $130 \times 10^3$ |
| Durometer Hardness, Shore D | ISO 868 | D | 80 | 76-80 |
| Coefficient of Friction | D-1894 | | -- | 0.3 |
| Deformation Under Load, 23°C, 1000 psi, 24 hr. | D-621 | % | -- | -- |
| **Thermal Property** | | | | |
| Melting Point | ISO R-527 | °C | 169 | 165-168 |
| Deflection Temperature (261 psi) | TMA | °C | 114-118 | -- |
| Oxygen Index | D-2863 | % | 43 | 43 |
| Max. Service Temperature | | °C | 149 | 150 |
| Thermal Conductivity | | W/m-K | 0.17-0.19 | 0.19-0.22 |
| Flammability | UL 94 | | V-O | V-O |
| **Electrical Property** | | | | |
| Surface Resistivity | D-257 | ohm-sq | -- | -- |
| Volume Resistivity | D-257 | ohm-cm | $1.5 \times 10^{14}$ | $1.1 \times 10^{15}$ |
| Dielectric Strength (10 mil) (3.2 mm for MP-10) | D-149 | V/mil | 1,600 | 325 |
| Dielectric Constant, 21°C, $10^3$ Hz, 60 Hz for MP-10 | D-150 | | 8.15-10.46 | 6.9 |
| Dissipation Factor, 21°C, 60 Hz | D-150 | | -- | 0.035 |
| Arc Resistance | D-495 | sec | 50-60 | 50-60 |

[1] Information provided by Atofina

[2] Information provided by Ausimont

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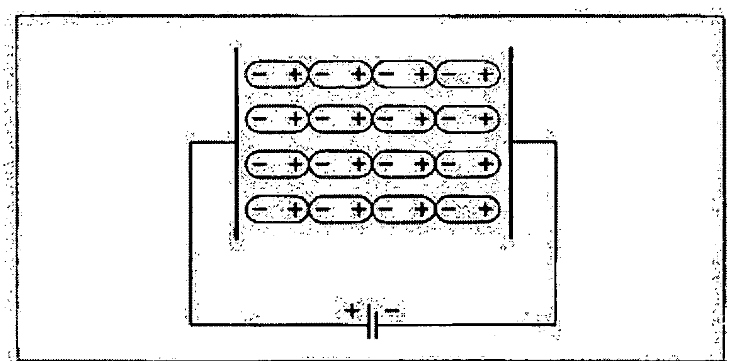
# Piezoelectric Transducers

Transducers that make use of the piezoelectric effect are widely used. These may be used to measure force by changing applied force to electrical energy or to generate force or movement from an electrical input. To understand the piezoelectric effect, we must first consider the dielectric properties of materials. These materials are all electrical insulators - they do not conduct current.

The application of an electric field to a dielectric material produces a displacement of charge within the material. This is known as dielectric polarization. This is shown in schematic form below.



Schematic representation of dielectric polarization.

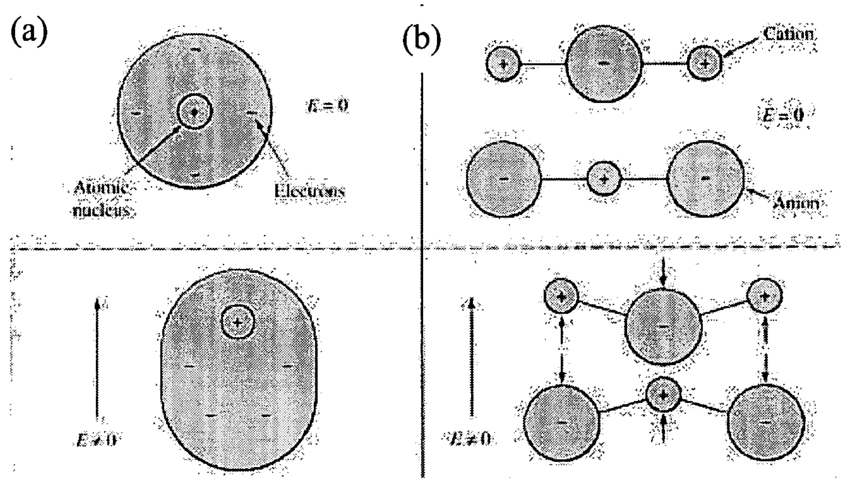
Because the material does not conduct, the interior of the material now has a potential gradient. The charge Q absorbed in the material is proportional to the applied voltage V. The proportionality constant is the capacitance of the piece of material. Hence we get:

$$Q = CV$$

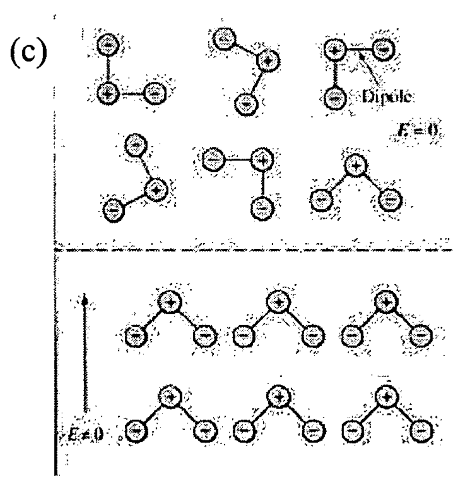
courses.washington.edu/mengr556/piezoelectric.pdf

The value of C depends on the material and on the geometry. The relevant property of the material is the dielectric constant $\in$.

There are several mechanisms of polarization:




a) Ionic polarization is due to the displacement of charged atoms with respect to other atoms in a molecule or a crystal lattice.
b) Electronic polarization is due to the displacement of electrons with respect to the nucleus of individual atoms.



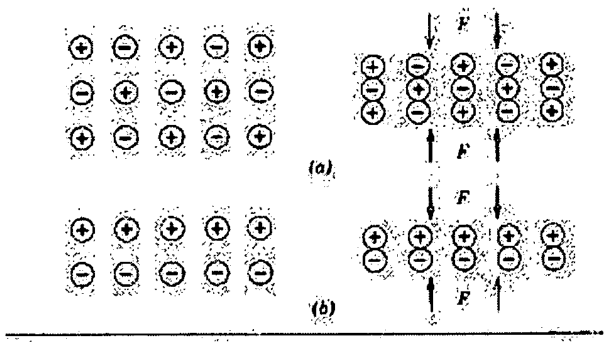
c) Orientational polarization arises if the material contains polar molecules, i.e. molecules that possess a permanent electric dipole moment. These molecules tend to align themselves in the direction of the applied field. This tendency is opposed by the thermal motions of the molecules thus making orientational polarization strongly temperature dependent.

All of these effects are also frequency dependent although this is unlikely to affect most measurements made at the frequencies of interest for mechanical transducers.

Piezoelectric and Ferroelectric effects.

The application of the electric field causes distortion of the original electron configuration or rotation of electric dipoles. This results in a dimensional change. This phenomenon, known as electrostriction, occurs in all dielectrics exposed to an electric field. The effect is usually very small and the resulting strain is independent of the direction of the applied field. There is no inverse effect, i.e. an applied strain does not induce an electric field if the dielectric crystal is symmetric.

However, if the charge distribution within the crystal is asymmetric, the lattice distortion due to an applied strain causes a net relative displacement between positive and negative charges within the lattice. This results in the appearance of an overall electric field. This is shown below:




a) with a symmetric charge distribution, the applied force F produces no net field
b) with an asymmetric distribution, a net change in field gradient is produced by F

The relation between the applied force and the electric field is:

$$\xi = \mathbf{g\ x\ F} \qquad \text{where:}$$

$\xi$ is the field intensity
g is the voltage output coefficient

The voltage output depends on the direction in which the piece of crystal is cut with respect to the crystalline axes.

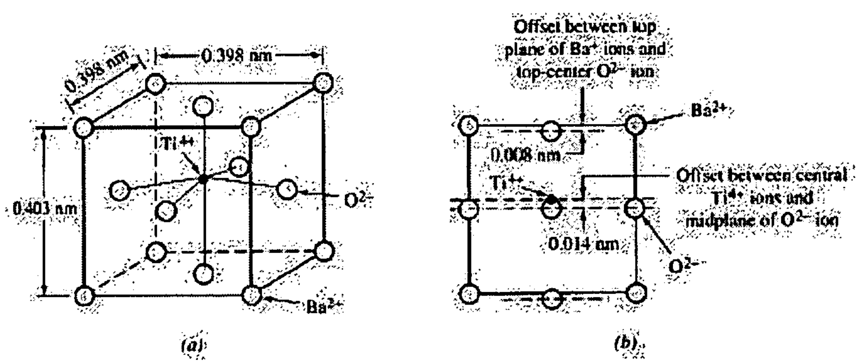
The inverse effect occurs when a voltage field is applied and results in mechanical distortion (strain $\varepsilon$) appearing in the crystal. In this case we have:

$$\varepsilon = \Gamma\xi \qquad \text{where:}$$

= the piezoelectric modulus

Typical piezoelectric crystals are quartz, cadmium sulfide, zinc sulfide, zinc oxide.

The ferroelectric effect is a very closely related phenomenon. The most significant difference from the piezoelectric effect is that, in ferroelectricity, there is a distinct hysteresis in the polarization vs. applied electric field relation (similar to the hysteresis seen in ferromagnetic materials). For practical applications, a number of ferroelectric materials exhibit high piezoelectric constants when compared to direct piezoelectric materials such as quartz. These materials are the ones most commonly used in transducers. Barium titanate ($BaTiO_3$) is a typical example. Above 120° C, this is a cubic crystal and, this being symmetric, it does not exhibit piezoelectric effects. Below 120° C, there is a phase change and the central Ti ion cannot fit into the central location as shown below.




It is displaced to one side and the now asymmetrical crystal now shows piezoelectric properties. The temperature below which this occurs is called the Curie temperature.

The most widely used piezoelectric materials are the PZT's (solid solutions of lead zirconate and lead titanate). These have Curie temperatures up to 490 ° C.

Force measurement:

A piezoelectric crystal can obviously be used as a force transducer. They are widely available both as load cells and as accelerometers. In the latter, a mass is connected to the base of the transducer via a piezoelectric crystal. The latter then measure the force needed to accelerate the mass. Thes transducers combine small size with reasonable sensitivity in a rugged, inexpensive package. They may have very good high frequency response. The major limitation is that they cannot make DC (steady state force) measurements. The input impedance of the amplifier used as a signal conditioner determines the low frequency response. The piezoelectric crystal is essentially a small capacitor. The charge induced by the applied force is stored in the capacitor but will leak away with time if the resistance seen by the electrodes on the opposite faces of the crystal is less then infinite. Special amplifiers with extremely high input impedance (1000's of MΩ), called charge amplifiers, are used. Great care must be taken with all cables used and with the surfaces of all parts to minimize leakage currents.

<u>Force and displacement generation</u>:

Most commercial ultrasound equipment uses piezoelectric transducers. In this case, a short electrical pulse or burst of high frequency voltage is applied to the transducer. This

causes the surface of the crystal to oscillate, usually at the resonant frequency of the crystal. If the acoustic impedance of the crystal is a reasonable match to the material that it contacts, sound waves are propagated into this material. Typically, echoes generated by these sound waves return to the crystal, which now acts as a force transducer and generates an electrical signal.

Piezoelectric crystals are also used as micro-positioning devices - on a very small scale.